CHAPTER ONE: LESSON ONE.

Baccalaureate Physics

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Chapter One

1 - 1 Physical Quantities and Units

The International System of Units (SI) is the modern form of the metric system. It is the primary system of measurement used globally and is widely applied in mechanics.

Physical Quantity	Standard Unit (SI)	Symbol
Mass	kilogram	kg
Length / Displacement	meter	m
Time	second	s

Attention A common misconception is treating the kilogram (kg) as a unit of weight. In physics, mass is measured in kilograms, whereas weight is a force resulting from gravity and must be measured in Newtons (N).

The following derived physical quantities are constructed from base units:

Physical Quantity	Derived Unit (SI)	Symbol
Speed / Velocity	meter per second	m/s
Acceleration	meter per second squared	m/s^2
Weight and Force	Newton	N

1 - 2 SI Prefixes: Multiples and Submultiples

Physical quantities are typically expressed with a numerical value and a unit of measurement. For instance, the distance between stars is vast, estimated at about 10^{17} m (approximately 100 quadrillion meters). Conversely, the distance between atoms in a solid is minute, about 10^{-9} m (one billionth of a meter).

To simplify the notation of such extreme values, we express them using powers of 10. Thus, the stellar distance is written as (1×10^{17} m) and the atomic distance as (1×10^{-9} m). Scientists have assigned specific prefixes to the multiplier $10^{\pm x}$, as detailed in the table below:

Factor (10^n)	10^{15}	10^{12}	10^{9}	10^{6}	10^{3}	10^{2}	10^{1}	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}
Prefix	peta	tera	giga	mega	kilo	hecto	deca	deci	centi	milli	micro	nano	pico	femto
Symbol	P	T	G	M	k	h	da	d	c	m	μ	n	p	f

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Mechanics

Introductory Example 1

Express the following physical quantities in SI base units:

a) 4 km b) 0.32 grams c) 5.1×10^6 km/h

$5.1 \times 10^6\ \text{km/h} = 5.1 \times 10^6 \times \frac{1000}{60 \times 60}$

$= 1.42 \times 10^6\ \text{m/s}$

The SI derived unit for speed is the meter per second.

$0.32\ \text{grams} = 0.32 \times 10^{-3}\ \text{kg}$

$= 3.2 \times 10^{-4}\ \text{kg}$

The SI base unit for mass is the kilogram.

$4\ \text{km} = 4 \times 1000\ \text{m}$

$= 4 \times 10^3\ \text{m}$

The SI base unit for length is the meter.

1 - 3 Scalars and Vectors

- **Vector Quantity:** A physical quantity that is completely described by both its magnitude and direction.

Examples of Vector Quantities:

Quantity	Description	Unit of Measurement (SI)
Displacement	Distance moved in a specified direction.	Meter ($\mathbf{m}$)
Velocity	The rate of change of displacement.	Meter per second ($\mathbf{m/s}$)
Acceleration	The rate of change of velocity.	Meter per second squared ($\mathbf{m/s^2}$)
Force / Weight	Determined by its magnitude, direction, and point of application.	Newton ($\mathbf{N}$)

- **Scalar Quantity:** A physical quantity that is completely described by its magnitude only.

Examples of Scalar Quantities:

Quantity	Description	Unit of Measurement (SI)
Distance	A measure of the length of the path taken.	Meter ($\mathbf{m}$)
Speed	A measure of how fast an object is moving.	Meter per second ($\mathbf{m/s}$)
Time	A measure of the duration of events.	Second ($\mathbf{s}$)
Mass	A measure of the amount of matter in an object.	Kilogram ($\mathbf{kg}$)

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Try It Yourself

Which of the following is considered a scalar quantity?

a) The weight of a man is $800\ \mathrm{N}$.

b) The displacement of a girl is $80\ \mathrm{m}$ East.

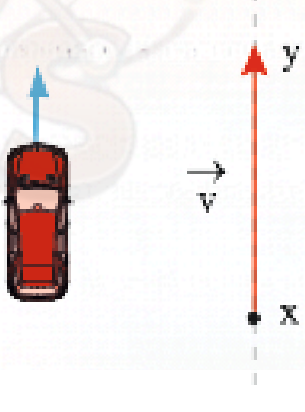
c) A force acting on an object is $20\ \mathrm{N}$.

d) The mass of an object is $80\ \mathrm{kg}$.

1 - 4 Representing Vector Quantities

Example: We can represent a vector quantity, such as the velocity of a car moving at $5\ \mathrm{m/s}$ Due North, using a drawn vector that consists of:

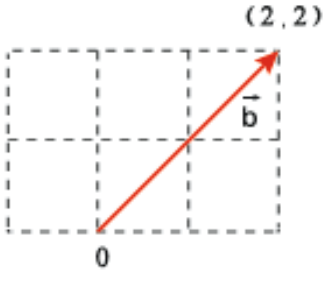
1. **Point of Application (Origin):** The starting point of the vector, labeled as point x.
2. **Magnitude:** Proportional to the length of the drawn vector. Using a chosen scale where $1\ \mathrm{cm}$ represents $1\ \mathrm{m/s}$, a line segment of $5\ \mathrm{cm}$ will accurately represent a velocity of $5\ \mathrm{m/s}$.
3. **Direction:** Indicated by an arrowhead pointing from the origin x towards point y (North).

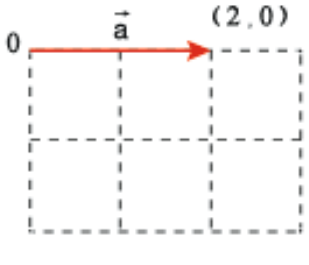


Representing Vectors in 2D Coordinates

Assuming that each side of a grid square represents one unit, we can express the vectors a and b as follows:

$$a = (2, 0)$$
$$b = (2, 2)$$





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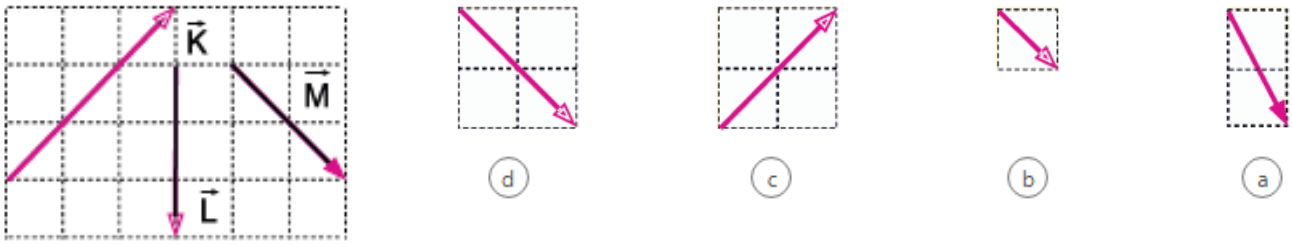
Introductory Example 2

Mechanics

The figure illustrates three coplanar vectors. Determine which option correctly represents the resultant vector: $K + 2L - M$



Explanation

$$K = (3,3) \qquad L = (0,-3) \qquad M = (2,-2)$$

$$\begin{aligned} K + 2L - M &= (3,3) + 2(0,-3) - (2,-2) \\ &= (3,3) + (0,-6) - (2,-2) \\ &= (3+0-2\,,\ 3-6+2) = (1,-1) \end{aligned}$$

1 - 5 Distance and Displacement

In the illustrated motion, an object leaves its initial position at $12\ \mathrm{m}$ and moves to the position $20\ \mathrm{m}$, then turns back to a final position at $4\ \mathrm{m}$ (this serves as an example of motion with a change in direction).

The **displacement** covered by the object, which represents the overall change in position, is:
$4 - 12 = -8\ \mathrm{m}$

The **distance** traveled by the object is $8\ \mathrm{m}$ during the outward trip and $16\ \mathrm{m}$ during the return trip, making the total distance covered $24\ \mathrm{m}$.

Note

Therefore, one must carefully distinguish between distance and displacement:

- Distance is a scalar quantity.
- Displacement is a vector quantity.

Hint

Numerically, the value of distance differs from that of displacement whenever the object changes its direction of motion.

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1 - 6 Graphical Vector Addition

Vector Addition:

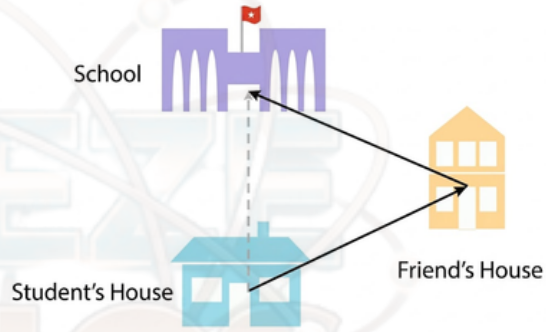
- **Method 1:** Graphical Method
- **Method 2:** Algebraic Method

Hint

When adding vectors, you must ensure they have identical units and describe similar physical quantities. For instance, it is illogical to add a velocity vector to a displacement vector, as they represent entirely different physical quantities.

First: The Graphical Method

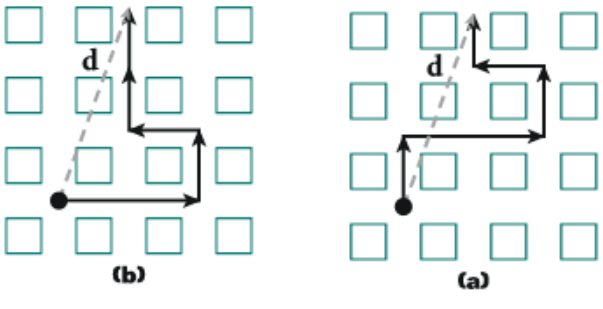
Suppose a student walks a distance of $1600\ \mathrm{m}$ to a friend's house, then walks another $1600\ \mathrm{m}$ to the school, as illustrated in the adjacent figure. The total displacement of the student during his journey from his house to the school is represented by the dashed line.



This direct straight-line path is the vector sum of the student's displacement from his home to his friend's house and his displacement from his friend's house to the school.

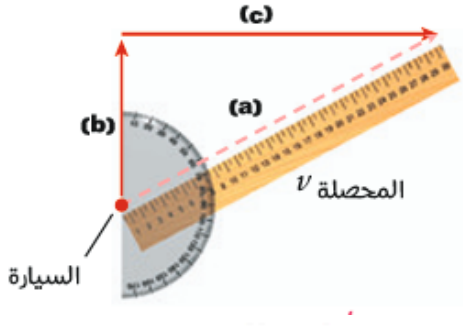
How can we find the resultant displacement graphically?

1. Draw the journey on paper using an appropriate scale; for example, let every $50\ \mathrm{m}$ on the ground be represented by $1\ \mathrm{cm}$ on the paper.
2. By measuring the length of the vector represented by the dashed line connecting the student's home to the school, and converting it using the chosen scale, we obtain the actual magnitude of the student's resultant displacement.



Note that:

The runner has covered the exact same displacement in both figures (a) and (b).



Note that:

The resultant velocity of a toy car can be determined using a ruler and a protractor, as shown for a car moving along vector (b) with velocity v_b followed by moving along vector (c) with velocity v_c.

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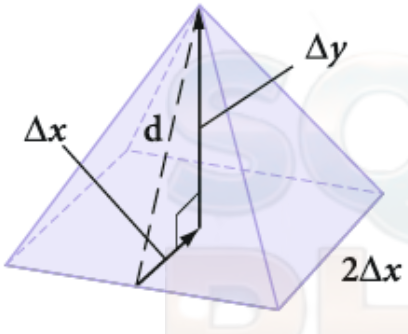
1 - 7 Resultant of Two Perpendicular Vectors Algebraically

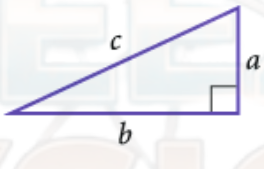
In the previous section, the resultant vector was found using the graphical method. However, this method can be time-consuming and its precision depends heavily on the accuracy of the drawing and scale. Therefore, the algebraic method provides a simpler and more exact approach.

Imagine a tourist climbing a pyramid in Egypt. He knows the pyramid's height and the width of its base, and he wants to determine the total displacement covered from the base to the apex.

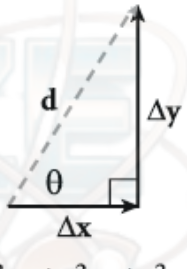
Assume the tourist climbs directly up the middle of one of the faces. As shown in the figure, if the vertical displacement (Δy) equals the height of the pyramid, the horizontal displacement (Δx) equals the distance from the center of the pyramid's base to its edge.

Notice that these two vectors are perpendicular, forming a right-angled triangle with the resultant displacement vector.





$$c^2 = a^2 + b^2$$



$$d^2 = \Delta x^2 + \Delta y^2$$

According to the Pythagorean theorem, the square of the hypotenuse equals the sum of the squares of the other two sides:

$$c^2 = a^2 + b^2$$

$$d^2 = (\Delta x)^2 + (\Delta y)^2$$

From the geometry of the figure, the angle θ can be calculated using trigonometry:

$$\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$$

Introductory Example 3

An archaeologist climbs the Great Pyramid of Giza. If the height of the pyramid is $136\ \mathrm{m}$ and the length of one side of its square base is $2.30 \times 10^2\ \mathrm{m}$, calculate the magnitude and direction of the displacement covered by the archaeologist from the base.

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Solution

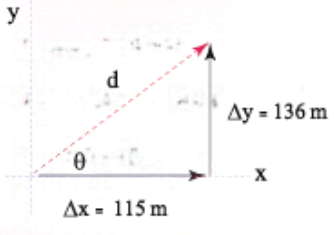
Chapter One

Given:

$\Delta y = 136\ \text{m}$

$\Delta x = 0.5 \times (2.30 \times 10^2) = 115\ \text{m}$

Representation:



Required:

$d = ?$ $\theta = ?$

$d = \sqrt{(\Delta x)^2 + (\Delta y)^2}$

$d = \sqrt{(115)^2 + (136)^2} = 178\ \text{m}$

$\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$

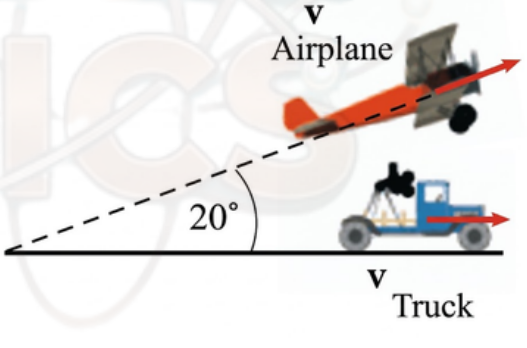
$\theta = \tan^{-1}\left(\frac{136}{115}\right) = 49.8^\circ$

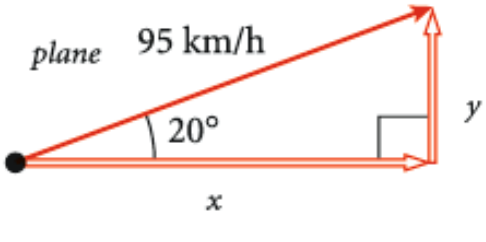
Evaluating the Result:
Notice that the calculated angle is greater than 45°. This makes logical sense because the height (Δy) is greater than half the length of the base (Δx).

1 - 8 Resolving a Vector into Two Perpendicular Components

A vector can be resolved into two mutually perpendicular components as follows:

A truck carrying camera equipment is moving to film the underside of an airplane. In order to successfully do this, the truck's speed must be exactly equal to the horizontal component of the airplane's velocity (v_x).





$v_x = v\cos 20^\circ$ $\quad v_x = v\cos\theta$

$v_y = v\sin 20^\circ$ $\quad v_x = 95\cos 20^\circ = 90\ \text{km/h}$

$v_y = v\sin\theta$

$v_y = 95\sin 20^\circ = 32.49\ \text{km/h}$

Introductory Example 4

Find the velocity components of a helicopter flying at a speed of $95\ \text{km/h}$ at an angle of 35° relative to the ground.

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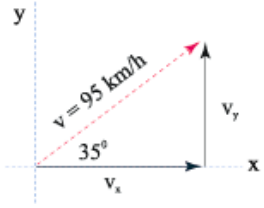
Explanation

Given: $v = 95\ \text{km/h}$ $\theta = 35^\circ$

Required: $v_x = ?$ $v_y = ?$

Representation:



Solution:

$$v_x = v\cos\theta$$
$$v_x = 95\cos 35^\circ = 78\ \text{km/h}$$

$$v_y = v\sin\theta$$
$$v_y = 95\sin 35^\circ = 54\ \text{km/h}$$

Verification:

$$v = \sqrt{(v_x)^2 + (v_y)^2}$$
$$v = \sqrt{(78)^2 + (54)^2} = 94.86\ \text{km/h}$$

Hint

Do not automatically assume that the cosine function is always used for the x-component and the sine function for the y-component. The choice of the appropriate trigonometric function depends entirely on the position of the given angle. Therefore, always verify which component is **adjacent** and which is **opposite** to the given angle before calculating.

1 - 9 Relative Velocity Vectors

$$v_{ba} = v_{be} + v_{ea}$$

Introductory Example 5 **Car (a) moves North at** $80\ \text{km/h}$ **and car (b) moves North at** $90\ \text{km/h}$**. Find the velocity of car (b) relative to car (a) (** v_{ba}**).**

Explanation

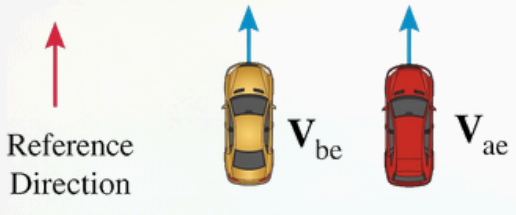
Assume Earth (e) is the reference frame for both cars.

The velocity of car (a) relative to Earth is: $v_{ae} = 80\ \text{km/h}$

The velocity of car (b) relative to Earth is: $v_{be} = 90\ \text{km/h}$

The velocity of car (b) relative to car (a) is:

$$v_{ba} = v_{be} - v_{ae} = 90 - 80 = 10\ \text{km/h}$$



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Introductory Example 6 Car (a) moves North at $80\ \text{km/h}$ and car (b) moves South at $90\ \text{km/h}$. Find the velocity of car (b) relative to car (a) (v_{ba}).

Explanation

Assume Earth (e) is the reference frame for both cars.

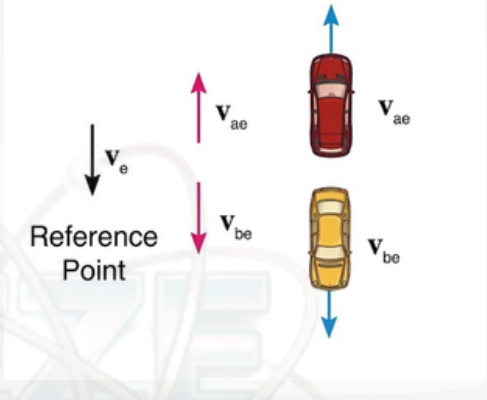
The velocity of car (a) relative to Earth is: $v_{ae} = 80\ \text{km/h}$

The velocity of car (b) relative to Earth is: $v_{be} = 90\ \text{km/h}$

The velocity of car (b) relative to car (a) is:

(Assuming South is the positive reference direction)

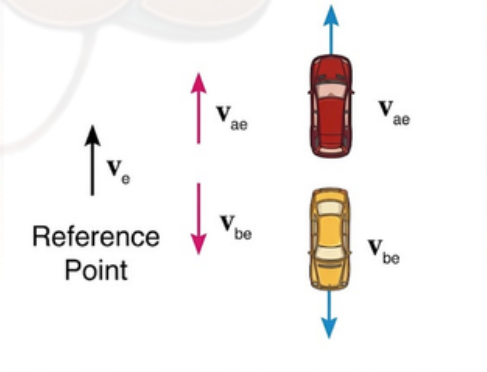
$$v_{ba} = v_{be} - v_{ae} = 90 - (-80) = 170\ \text{km/h}$$



Alternative Solution

By changing the reference direction (Assuming North is the positive direction):

$$v_{ba} = v_{be} - v_{ae} = -90 - 80 = -170\ \text{km/h}$$



Introductory Example 7

A boat heads Due North across a wide river with a speed of $10\ \text{km/h}$ relative to the water. If the river's water flows with a uniform speed of $5\ \text{km/h}$ Due East, determine the velocity of the boat relative to an observer standing on the shore.

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Explanation

Chapter One

Given:

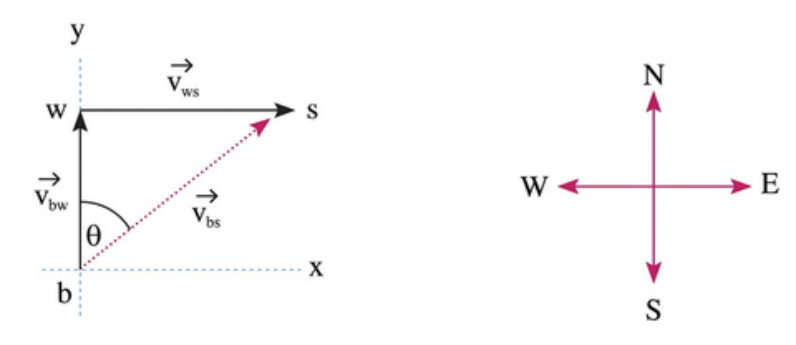
Velocity of the boat (b) relative to water (w):
$v_{bw} = 10\ \text{km/h}$ (Due North)

Velocity of the water (w) relative to the shore (s):
$v_{ws} = 5\ \text{km/h}$ (Due East)

Required:

Velocity of the boat (b) relative to the shore (s):
$v_{bs} = ?$

Representation



Solution:

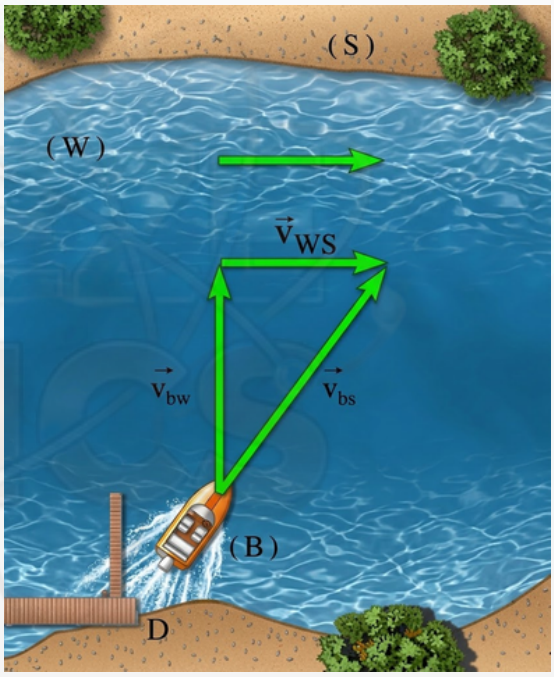
$$v_{bs} = v_{bw} + v_{ws}$$

$$v_{bs} = \sqrt{(v_{bw})^2 + (v_{ws})^2}$$

$$v_{bs} = \sqrt{(10)^2 + (5)^2} = 11.18\ \text{km/h}$$

$$\theta = \tan^{-1}\left(\frac{v_{ws}}{v_{bw}}\right) = 26.6^\circ$$

The boat moves with a speed of $11.18\ \text{km/h}$ in a direction 26.6° East of North relative to the shore.



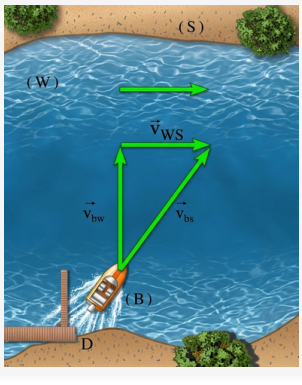
Introductory Example 8

A boat travels in still water at a speed of $4\ \text{m/s}$. It moves across a straight river where the current speed is $3\ \text{m/s}$. If the boat's bow points perpendicular to the riverbank, find the speed of the boat relative to the riverbank.

Solution:

$$v_{BS} = v_{BW} + v_{WS}$$

$$v_{BS} = \sqrt{(4)^2 + (3)^2} = 5\ \text{m/s}$$



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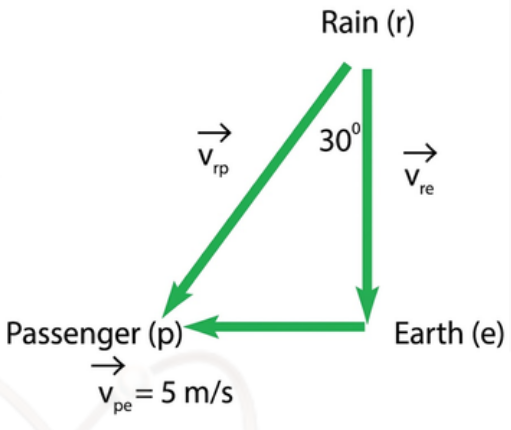
Introductory Example 9 **Mechanics**

Rain falling vertically appears to a passenger in a subway train, which is moving across an open section at a speed of $5\ \text{m/s}$, as if it is falling at an angle of 30° with the vertical. Calculate the actual speed of the raindrops.

Solution

$$\tan\theta = \frac{v_{pe}}{v_{re}} = \frac{5}{v_{re}}$$

$$v_{re} = \frac{5}{\tan 30^\circ} = 8.6\ \text{m/s}$$



Introductory Example 10

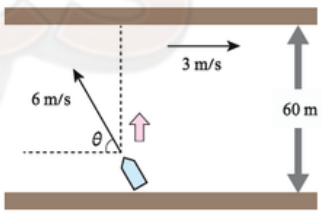
A boat with a speed of $6\ \text{m/s}$ in still water navigates a straight river where the current speed is $3\ \text{m/s}$. The boat is steered such that its resultant path crosses perpendicularly to the riverbank.

1. **Find the angle θ that the boat's heading makes with the riverbank.**
2. **If the width of the river to be crossed is $60\ \text{m}$, find the time required for the crossing.**

Solution

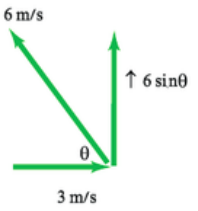
$$\cos\theta = \frac{3}{6} = \frac{1}{2}$$

$$\theta = 60^\circ$$



$$v_y = v\sin\theta = 6\sin 60^\circ$$

$$= 3\sqrt{3}\ \text{m/s}$$



$$t = \frac{x}{v_y} = \frac{60}{3\sqrt{3}} = 11.55\ \text{s}$$

Introductory Example 11

A person is riding a bicycle heading West at $5\ \text{m/s}$. He feels a wind blowing from the North at $5\ \text{m/s}$. Determine the direction and speed of the wind relative to the ground.

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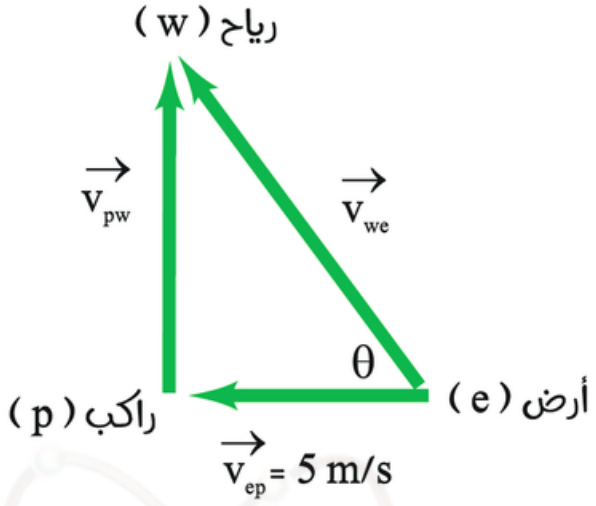
Solution

$$\tan\theta = \frac{v_{pw}}{v_{ep}} = \frac{5}{5} = 1$$
$$\theta = 45^\circ$$

$$v_{ew} = v_{ep} + v_{pw}$$
$$= \sqrt{(5)^2 + (5)^2}$$
$$= 5\sqrt{2}\ \text{m/s}$$



Introductory Example 12

An airplane ascends at a constant speed of $50\ \text{m/s}$ at an angle of 30° to the horizontal. Find the altitude gained by the airplane in $10\ \text{s}$.

Solution

$$v_y = v\sin\theta \qquad v_y = 50\sin 30^\circ \qquad h = v_y \cdot t = 50\sin 30^\circ \times 10 = 250\ \text{m}$$

Introductory Example 13

To an observer looking out the window of Train A, which is moving on a horizontal track at a speed of $10\ \text{m/s}$, vertically falling rain appears to fall at an angle of 45° to the vertical.

1. **Find the actual speed of the raindrops.**
2. **To an observer looking out the window of Train B, which passes next to Train A, the rain appears to fall at an angle of 60° to the vertical. Find the speed of Train B.**

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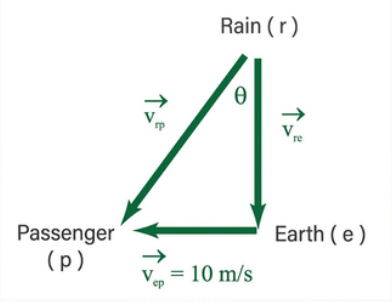
Solution

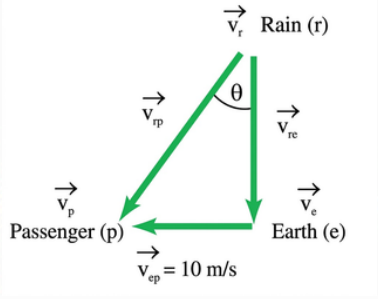
Part 1 (Train A)



$$\tan\theta = \frac{v_{ep}}{v_{re}} = \frac{10}{v_{re}}$$

$$v_{re} = \frac{10}{\tan 45^\circ} = 10 \text{ m/s}$$

Part 2 (Train B)



$$\tan\theta = \frac{v_{ep}}{v_{re}} = \frac{v_{ep}}{10}$$

$$v_{ep} = v_{re} \times \tan 60^\circ = 10 \times \tan 60^\circ = 17.3 \text{ m/s}$$

Introductory Example 14

Car A moves East at a speed of $20\ \mathbf{m/s}$ and Car B moves North at a speed of $20\ \mathbf{m/s}$. Find the magnitude and direction of the relative velocity of Car B with respect to Car A.

Solution

$$v_{BA} = v_{Be} + v_{eA}$$

$$v_{BA} = \sqrt{(20)^2 + (20)^2} = 20\sqrt{2} \text{ m/s}$$

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Exercises Choose the correct answer:

1 An airplane has a velocity of $200\ \mathrm{m/s}$ Due North relative to the wind. It moves through a wind blowing at $50\ \mathrm{m/s}$ Due West. The resultant velocity of the airplane relative to the Earth is:

(a) $150\ \mathrm{m/s}$ (b) $200\ \mathrm{m/s}$ (c) $206\ \mathrm{m/s}$ (d) $250\ \mathrm{m/s}$

Explain your answer:

2 An airplane flies Due South at a speed of $500\ \mathrm{km/h}$. A wind blows from East to West at a speed of $45\ \mathrm{km/h}$. Find the resultant velocity of the airplane relative to the Earth.

(a) $502\ \mathrm{km/h}$ at angle 265° (b) $502\ \mathrm{km/h}$ at angle 85°

(c) $520\ \mathrm{km/h}$ at angle 5° (d) $545\ \mathrm{km/h}$ at angle 265°

Explain your answer:

3 A boat has a speed of $8\ \mathrm{m/s}$ in still water. It is steered to cross a river where the water current flows at $6\ \mathrm{m/s}$. What is the speed of the boat while crossing the river?

(a) $5.3\ \mathrm{m/s}$ (b) $6\ \mathrm{m/s}$ (c) $8\ \mathrm{m/s}$ (d) $10\ \mathrm{m/s}$

Explain your answer:

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4 A boat travels at a speed of $10\ \mathrm{m/s}$ in still water. It crosses a river, resulting in an actual straight-line displacement of $1.6\ \mathrm{km}$ to the opposite bank. If the river current flows at $5\ \mathrm{m/s}$, how much time will it take to cross the river?

(a) $5.3\ \mathrm{min}$ (b) $2.7\ \mathrm{min}$ (c) $2.4\ \mathrm{min}$ (d) $1.8\ \mathrm{min}$

Explain your answer:

5 A swimmer heads directly across a river of width $200\ \mathrm{m}$ and reaches the opposite bank in $6\ \mathrm{min}$ and $40\ \mathrm{s}$. If she drifts downstream a distance of $480\ \mathrm{m}$, what is her speed in still water?

(a) $0.5\ \mathrm{m/s}$ (b) $1.2\ \mathrm{m/s}$ (c) $1.4\ \mathrm{m/s}$ (d) $1.8\ \mathrm{m/s}$

Explain your answer:

1(c) 2(a) 3(d) 4(c) 5(a)

6 Train X moves at a speed of $40\ \mathrm{km/h}$ Due East relative to the Earth. Train Y moves Due West at a speed of $40\ \mathrm{km/h}$ relative to Train X. The velocity of Train Y relative to the Earth is:

(a) $40\ \mathrm{km/h}$ Due West (b) $40\ \mathrm{km/h}$ Due East

(c) Zero (d) $80\ \mathrm{km/h}$ Due West

Explain your answer:

7 Two cars, X and Y. Car X moves relative to the Earth at a speed of $2v$ Due East. If the velocity of Car Y relative to Car X is $3v$ Due West, then the magnitude and direction of the velocity of Car Y relative to the Earth is:

(a) v Due West (b) v Due East

(c) $3v$ Due West (d) $3v$ Due East

Explain your answer:

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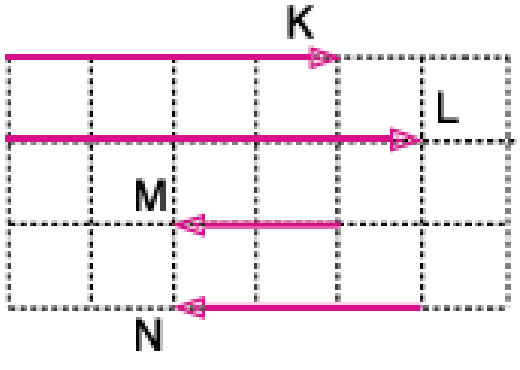
8 The vector diagram shows the velocity vectors of four cars. Which of the following represents the greatest relative speed?



(a) v_{LN} (b) v_{KN}

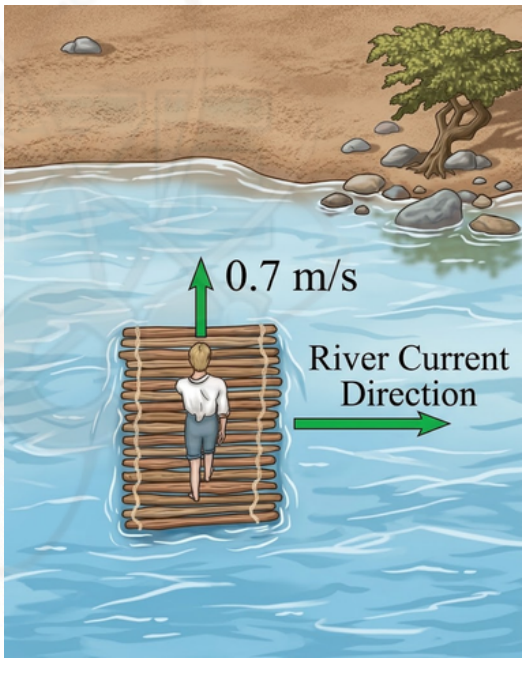
(c) v_{KM} (d) v_{KL}

Explain your answer:

.....

.....

9 A boy moves on a wooden raft at a speed of $0.7\ \mathrm{m/s}$ perpendicular to the direction of the river current, which flows at a speed of $1.5\ \mathrm{m/s}$. What is the velocity of the boy relative to the riverbank?



(a) $1.66\ \mathrm{m/s}$ (b) $2.3\ \mathrm{m/s}$

(c) $1.2\ \mathrm{m/s}$ (d) $2.6\ \mathrm{m/s}$

Explain your answer:

.....

.....

10 A swimmer heads directly across a river of width $200\ \mathrm{m}$ and reaches the opposite bank in $6\ \mathrm{min}$ and $40\ \mathrm{s}$. If she drifts downstream a distance of $480\ \mathrm{m}$, what is the speed of the river current?

(a) $0.5\ \mathrm{m/s}$ (b) $1.2\ \mathrm{m/s}$ (c) $1.4\ \mathrm{m/s}$ (d) $1.8\ \mathrm{m/s}$

Explain your answer:

6(c) 7(a) 8(a) 9(a) 10(b)

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Exercises Essay Questions:

1 A roller coaster car moves a horizontal distance of $85\ \mathbf{m}$, then travels a distance of $45\ \mathbf{m}$ at an angle of 30° above the horizontal. What is the total displacement of the car? (Using the graphical method).

Explain your answer:

2 A novice pilot sets the plane's controls, thinking it will fly at a velocity of $2.5 \times 10^{2}\ \mathbf{km/h}$ Due North. If the wind velocity is $75\ \mathbf{km/h}$ Due Southeast, what is the resultant velocity of the airplane? (Using the graphical method).

Explain your answer:

3 Water used in fountains is recycled. If a drop of water in a fountain travels through a system of length $85\ \mathbf{m}$ and returns to the same starting point, what is the displacement of the water drop during one complete cycle?

Explain your answer:

(Zero)

4 A truck driver is trying to deliver some furniture. First, he travels $8\ \mathbf{km}$ Due East. Then, he turns and travels $3\ \mathbf{km}$ Due West. Finally, he turns again and travels $12\ \mathbf{km}$ Due East to his destination.

a) What is the total distance traveled by the driver?

b) What is the total displacement of the driver?

Explain your answer:

($x = 23\ \mathrm{km}, d = 17\ \mathrm{km}$)

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5 A pirate moved a distance of $45\ \mathrm{m}$ Due North, then turned and moved a distance of $7.5\ \mathrm{m}$ Due East. What is the displacement covered by the pirate to reach the treasure?

Explain your answer:

($45.6\ \mathrm{m}$)

6 Kamel passed a football a distance of $6\ \mathrm{m}$ directly across the field to Hamdy, who then kicked the ball directly down the field a distance of $14.5\ \mathrm{m}$ to Hamza. What is the total displacement of the ball between Kamel and Hamza?

Explain your answer:

($15.7\ \mathrm{m}$)

7 A hummingbird is at a height of $3.4\ \mathrm{m}$ above the ground. It flies a distance of $1.2\ \mathrm{m}$ in a straight horizontal path, and upon seeing a flower below, it drops directly down a distance of $1.4\ \mathrm{m}$ to hover in front of the flower. What is the total displacement of the hummingbird?

Explain your answer:

($1.8\ \mathrm{m}$)

8 A truck is moving directly beneath an airplane. What must the truck's speed be to remain directly beneath the airplane, given that the airplane is moving at a speed of $105\ \mathrm{km/h}$ at an angle of 25° with the ground? What is the vertical component of the airplane's velocity?

Explain your answer:

($v_x = 95\ \mathrm{km/h}, v_y = 44\ \mathrm{km/h}$)

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9 A truck climbs a hill with an incline angle of 15°. If the truck maintains a constant speed of $22\ \mathrm{m/s}$, what are the horizontal and vertical components of its velocity?

Explain your answer:

($v_x = 21\ \mathrm{m/s}, v_y = 5.7\ \mathrm{m/s}$)

10 What are the horizontal and vertical components of a cat's displacement when it climbs $5\ \mathrm{m}$ directly up a tree?

Explain your answer:

($d_x = 0, d_y = 5\ \mathrm{m}$)

11 A passenger sits at the back of a train moving at a speed of $15\ \mathrm{m/s}$ relative to the ground. He throws a ball with a speed of $15\ \mathrm{m/s}$ in the direction opposite to the train's motion. What is the velocity of the ball relative to the ground the moment it leaves the thrower's hand?

Explain your answer:

($0\ \mathrm{m/s}$)

12 A spy runs from the bow (front) of an aircraft carrier towards its stern (back) at a speed of $3.5\ \mathrm{m/s}$. If the aircraft carrier is moving forward at a speed of $18\ \mathrm{m/s}$, what is the velocity of the spy as observed by someone on a nearby stationary submarine?

Explain your answer:

($14.5\ \mathrm{m/s}$)

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13 A ferry crosses a river. The ferry is heading Due North at a speed of $2.5\ \mathrm{m/s}$ relative to the water. If the river current's speed is $3\ \mathrm{m/s}$ Due East, what is the velocity of the ferry relative to the Earth?

Explain your answer:

($3.9\ \mathrm{m/s}$)

14 A woman rides a 10-speed bicycle at a speed of $9\ \mathrm{m/s}$ relative to the Earth. She passes a young child on a tricycle moving in the opposite direction. If the child's speed relative to the Earth is $1\ \mathrm{m/s}$, what is the apparent velocity of the child relative to the woman?

Explain your answer:

($10\ \mathrm{m/s}$)

15 A girl in an airport rolls a ball Due North on a moving walkway that moves Due East. If the speed of the ball relative to the walkway is $0.15\ \mathrm{m/s}$ and the walkway moves at a speed of $1.5\ \mathrm{m/s}$, what is the speed of the ball relative to the Earth?

Explain your answer:

($1.5\ \mathrm{m/s}$)

16 Describe the motion of the following objects relative to each observer:

a) A person standing on a train platform as seen by a passenger on a train moving North.

b) A train moving North as seen by a person standing on the platform.

c) A ball dropped by a child walking at $1\ \mathrm{m/s}$, as seen by the child.

d) A ball dropped by a child walking at $1\ \mathrm{m/s}$, as seen by a stationary observer nearby.

Explain your answer:

(a- Moving South with a speed equal to the train's speed. b- Moving North. c- Falling vertically downwards. d- Moving in a curved path.)

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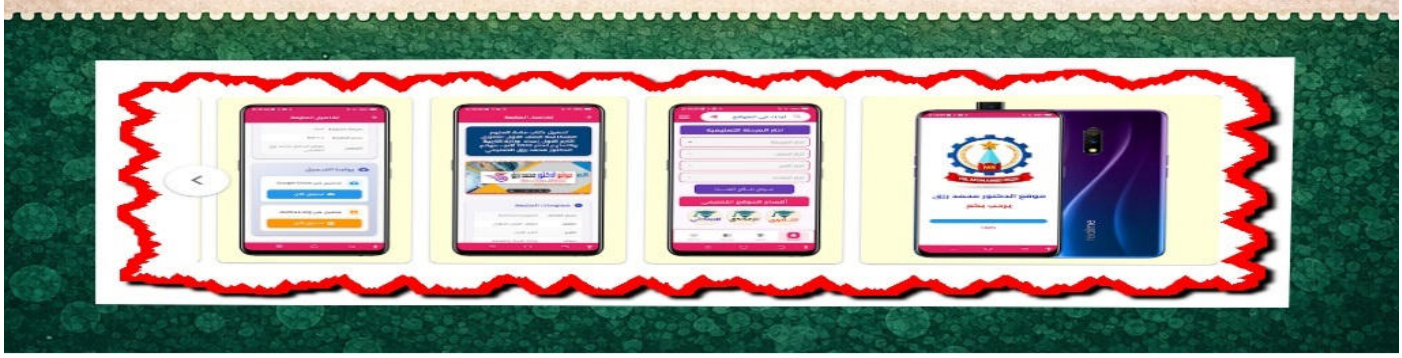

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